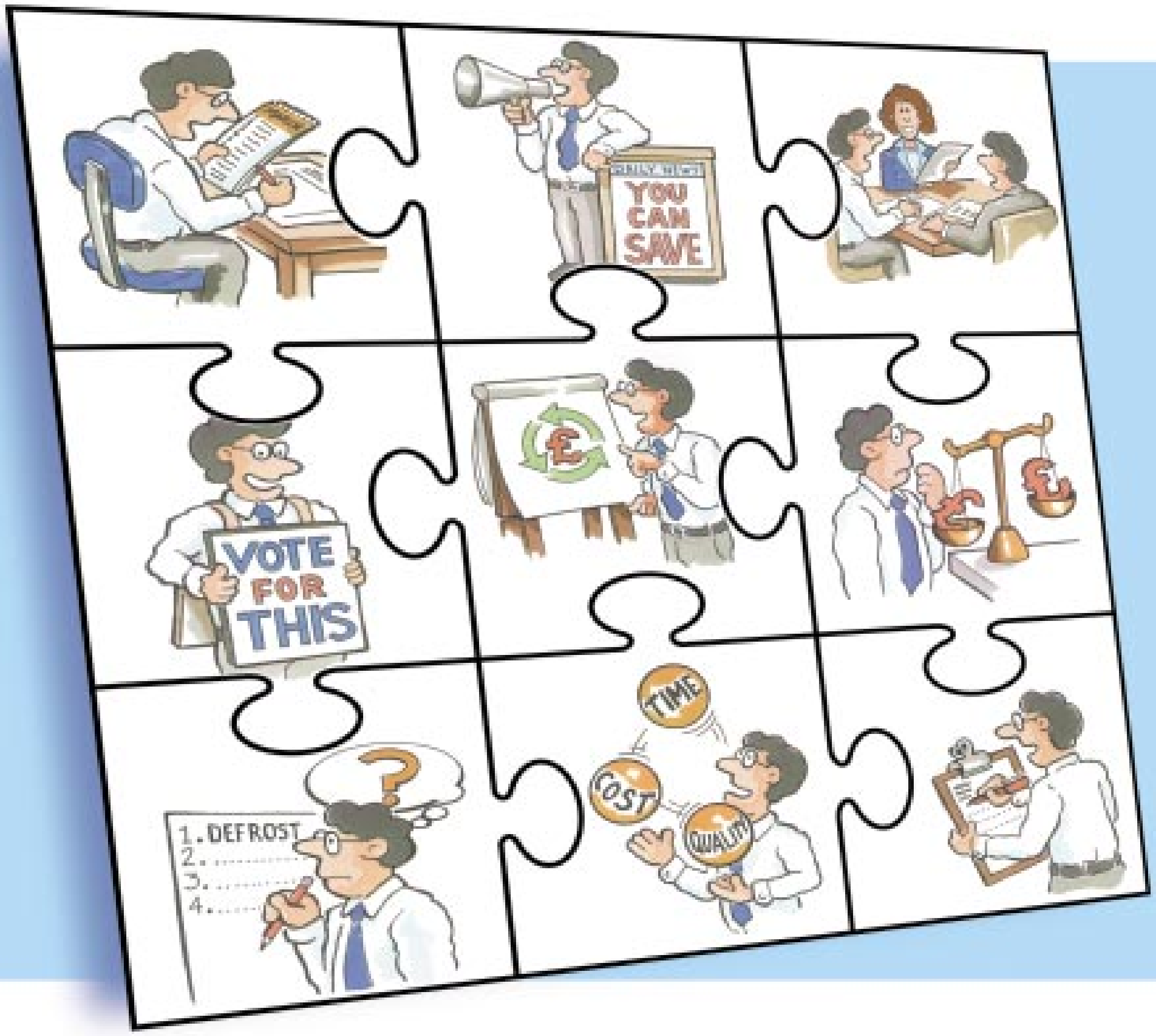
GOOD PRACTICE GUIDE 236

Refrigeration efficiency investment

Putting together a persuasive case



GOOD PRACTICE GUIDE 236

ARCHIVED DOCUMENT

ENERGY EFFICIENCY

BEST PRACTICE PROGRAMME

ETSU would like to thank the British Refrigeration Association, the Institute of Refrigeration and also the many others who helped during the planning and preparation of this Guide.

REFRIGERATION EFFICIENCY INVESTMENT
PUTTING TOGETHER A PERSUASIVE CASE

This booklet is No 236 in the Good Practice Guide series, and is intended to provide information so that you can develop a successful approach to refrigeration efficiency investment. It shows how to identify the best projects and persuade management to invest capital in them.

Prepared for the Department of the Environment, Transport and the Regions by:

ETSU
Harwell
Didcot
Oxfordshire
OX11 0RA

and

March Consulting Group Ltd
Telegraphic House
Waterfront Quay
Salford Quays
Manchester
M5 2XW

LIST OF RELEVANT GOOD PRACTICE GUIDES

2. GUIDANCE NOTES FOR REDUCING ENERGY CONSUMPTION OF ELECTRIC MOTORS AND DRIVES

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Copies of these Guides may be obtained from:

Energy Efficiency Enquiries Bureau
ETSU
Harwell
Didcot
Oxfordshire
OX11 0RA

Tel No: 01235 436747. Fax No: 01235 433066. E-mail: etsuenq@aeat.co.uk

Overseas customers please remit £3 per copy (minimum of £6) with order to cover cost of packaging and posting. Please make cheques, drafts or money orders payable to ETSU.

FOREWORD

This Guide is part of a series produced by the Government under the Energy Efficiency Best Practice Programme. The aim of the programme is to advance and spread good practice in energy efficiency by providing independent, authoritative advice and information on good energy efficiency practices. Best Practice is a collaborative programme targeted towards energy users and decision makers in industry, the commercial and public sectors, and building sectors including housing. It comprises four inter-related elements identified by colour-coded strips for easy reference:

— *Energy Consumption Guides:* (blue) energy consumption data to enable users to establish their relative energy efficiency performance;

— *Good Practice Guides:* (red) and *Case Studies:* (mustard) independent information on proven energy-saving measures and techniques and what they are achieving;

— *New Practice projects:* (light green) independent monitoring of new energy efficiency measures which do not yet enjoy a wide market;

— *Future Practice R&D support:* (purple) help to develop tomorrow's energy efficiency good practice measures.

If you would like any further information on this document, or on the Energy Efficiency Best Practice Programme, please contact the Environment and Energy Helpline on 0800 585794. Alternatively, you may contact your local service deliverer – see contact details below.

ENGLAND

London
Govt Office for London
6th Floor
Riverwalk House
157-161 Millbank
London
SW1P 4RR
Tel 020 7217 3435

East Midlands
The Sustainable Development Team
Govt Office for the East Midlands
The Belgrave Centre
Stanley Place
Talbot Street
Nottingham
NG1 5GG
Tel 0115 971 2476

North East
Sustainability and Environment Team
Govt Office for the North East
Wellbar House
Gallowgate
Newcastle-upon-Tyne
NE1 4TD
Tel 0191 202 3614

North West
Environment Team
Govt Office for the North West
Cunard Building
Pier Head
Water Street
Liverpool
L3 1QB
Tel 0151 224 6401

South East
Sustainable Development Team
Govt Office for the South East
Bridge House
1 Walnut Tree Close
Guildford
Surrey
GU1 4GA
Tel 01483 882532

East
Sustainable Development Awareness Team
Govt Office for the East of England
Heron House
49-53 Goldington Road
Bedford
MK40 3LL
Tel 01234 796194

South West
Environment and Energy Management Team
Govt Office for the South West
The Pithay
Bristol
Avon
BS1 2PB
Tel 0117 900 1700

West Midlands
Regional Sustainability Team
77 Paradise Circus
Queensway
Birmingham
B1 2DT
Tel 0121 212 5300

Yorkshire and the Humber
Sustainable Development Unit
Govt Office for Yorks and the Humber
PO Box 213
City House
New Station Street
Leeds
LS1 4US
Tel 0113 283 6376

NORTHERN IRELAND
IRTU Scientific Services
17 Antrim Road
Lisburn
Co Antrim
BT28 3AL
Tel 028 9262 3000

SCOTLAND
Energy Efficiency Office
Enterprise and Lifelong Learning Dept
2nd Floor
Meridian Court
5 Cadogan Street
Glasgow
G2 6AT
Tel 0141 242 5835

WALES
Business and Environment Branch
National Assembly for Wales
Cathays Park
Cardiff
CF10 3NQ
Tel 029 2082 5172

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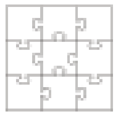

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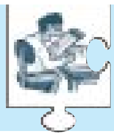

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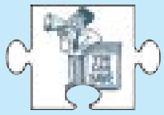

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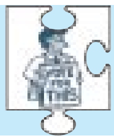

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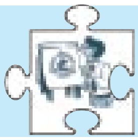

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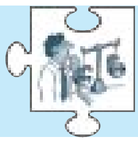

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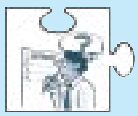

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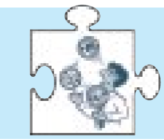

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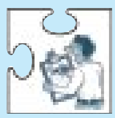

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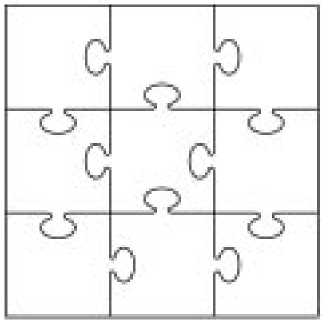

WHY YOU SHOULD READ THIS GUIDE

Most well-informed refrigeration managers will have no shortage of ideas on ways to cut the running costs or improve the reliability of plant in their care. There is usually plenty of scope. But obtaining funding from management is often extremely difficult - there always seems to be something ‘more important’ to spend money on than this crucial utility.

However, there are tried and trusted ways to make sure that you have the best possible chance of success - that means success in identifying the best projects, and success in persuading management that scarce resources are being well spent. Many perfectly good refrigeration efficiency projects fail to obtain capital funding because of poor presentation of the financial and business advantages.

This Good Practice Guide will enable energy managers to overcome this problem. Refrigeration is certainly not an area which should be ignored. In fact, for many companies, there is greater potential for energy savings in refrigeration and air-conditioning than for other aspects of electricity usage. It is estimated that savings of up to 25% are easily achievable without technical risk.

The beauty of this Guide is that it is not aimed only at financial wizards or technical managers, but at anyone with the responsibility for saving energy. Using a powerful combination of everyday language and real examples, it will guide you through the financial maze. As with most things in life, the key to success is planning - so, before rushing off to write your proposal, find out the precise requirements of your organisation and, before submitting your proposal, check that these have been met. Failure may mean a potentially good investment is rejected. The Guide stresses that the way to persuade your company to invest scarce resources is to prepare a thorough and convincing proposal. You will be competing with other projects, so improve your chances by making sure that all the key players are on your side.

The Guide also summarises which other publications from the Energy Efficiency Best Practice Programme can help you improve your refrigeration efficiency.

1. PLANNING YOUR CASE

Many perfectly good refrigeration efficiency projects fail to obtain capital funding because of poor presentation of their financial and business advantages.

This Guide will help improve your capital proposals

This Good Practice Guide aims to help you to overcome this problem and develop a successful approach to refrigeration efficiency investment. As in a jigsaw puzzle, this involves putting a number of pieces into place to form a total picture; if any one of the pieces is missing then the puzzle cannot be completed. In the Refrigeration Investment Puzzle there are nine pieces, each of which was described in the contents. You will probably have some of these in place; to fill in the missing pieces, read the appropriate section of the Guide carefully to find what steps you should take. Each 'piece' of this Guide will help you provide appropriate information, analysis or presentation for the capital proposal.

The first step is good planning

If you are to make a persuasive case, it is essential that you plan your approach carefully and meet the expectations of your company's capital approvals committee. Your project planning should allow sufficient time and resources to do justice to the potential benefits. A good starting point is to review the information required. Every organisation has its own format in which capital expenditure proposals must be presented. Most submissions will require as a minimum:

- a brief explanation of the reason for the proposed expenditure;
- details of the proposed plant, highlighting why this particular piece of equipment has been selected;
- a summary of the main features of the proposed purchase contract;
- a detailed build-up of the capital sum required and the payment stages involved;
- a summary of the anticipated savings resulting from the investment, with supporting details;
- a statement of the resulting pay-back period/return on investment/net present value (whichever is required) with supporting detail.

Understand the required format of capital proposals

It is essential that you understand the precise requirements within your organisation and make certain that these are met when submitting your proposal. Failure to do so may result in a potentially good investment being rejected.

Use teamwork to compete effectively for limited resources

Your proposal must be both thorough and convincing. The advice in this Guide will help you write such a proposal. Putting the financial data in the right format is crucial. The Guide encourages teamwork between technical and financial staff to achieve this. Piece 3 of the jigsaw introduces the team approach and Pieces 5 and 6 help explain some key financial mechanisms. Understanding the timings of the investment cycle in your company is important. Making proposals even one month late can completely miss the annual budgeting process. Conversely, having up-to-date knowledge of the availability of funds may enable you to get extra projects approved (for example, if another budget is underspent).

Optimise the timing of your submission

The financial aspect is not the whole story. Many projects get approval because of overriding issues (e.g. replacement of unreliable plant) or secondary benefits (e.g. environmental performance). Piece 8 describes the prioritisation process and Piece 4 gives practical tips about how to present these benefits.

You will need to show that you are proposing the best project and that it is a worthwhile scheme in which your organisation can invest scarce resources. This implies thorough research and comparison of competing efficiency projects. Piece 7 suggests a structured approach to identification of projects and Piece 9 describes the data you will need for analysis.

The Glossary at the end will help you to understand the jargon if you are new to refrigeration and/or financial appraisal.

1. PLANNING YOUR CASE

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2. THE POTENTIAL TO SAVE

Approximately 15% of all UK electricity produced is used for refrigeration and air-conditioning, making it one of the most important energy-using technologies, comparable in consumption with, for example, lighting.

There are excellent opportunities to improve the efficiency of refrigeration systems in all sectors. A greater potential exists for refrigeration and air-conditioning savings than for electricity in general. For an 'average' site, general electricity savings in the region of 10% to 15% can be achieved reasonably easily. However for a refrigeration system, cost-effective savings of 20% to 25% are usually achievable without technical risk. This level of saving has been demonstrated repeatedly throughout a wide range of end-user sectors.

Important cost saving potential

Many companies have not yet exploited these opportunities because it is often difficult to secure approval for investment in energy-efficient refrigeration. There are many reasons for this but the most important barriers include:

- a lack of awareness of the potential savings;
- difficulties in identifying the most cost-effective projects;
- problems in convincing management of the financial benefits.

These barriers are particularly relevant for refrigeration - it is not usually an important issue to a company until things start to get warm!

You wouldn't neglect your boiler....

Compare boilers and refrigeration for a few moments and the lack of awareness becomes clearer! Most plant engineers understand boiler efficiency and make sure that they buy efficient boilers and monitor them regularly in order to maintain high efficiency. Who would sanction the purchase of a 60% efficient boiler?

With refrigeration plant the situation is reversed. Efficiency concepts are more complex and not well understood. Few end-users assess efficiency carefully before buying and often end up with plant that is 20% to 30% below optimum efficiency. Some modern systems are less efficient than those installed 30 or 40 years ago! Refrigeration plant tends to be reliable and it is often operated with minimal maintenance. Without regular analysis of performance data, loss of efficiency is often not detected until cooling service is completely lost.

....take care of your refrigeration!

Efficiency of refrigeration plant deserves attention

People often make the assumption that improved refrigeration efficiency always requires extra investment. This is certainly not the case. Some improvements can be made without cost and others actually save capital!

Zero cost measures often relate to plant management. Improved control of temperature and plant sequencing can often save a lot of money. One user saved £7,500 per year simply by prioritising the use of the more efficient of two apparently similar compressors!

Improved efficiency does not always cost money!

Negative cost measures. For a new refrigeration plant an efficient design can actually cost less. For example, if you are able to eliminate a refrigerated heat load and replace it with 'free cooling' you will certainly save money.

If you use a thorough and well-structured approach you are likely to find many attractive refrigeration efficiency investment projects for your plant.

3. THE TEAM APPROACH

Teamwork improves projects

Team working will improve the chances of securing approval for your refrigeration efficiency project. Preparing a good capital expenditure appraisal can be a complex task and few individuals have all the necessary knowledge and skills. Working as a team will ensure these skills are available.

Find a structure that suits the project and the company

Teams can be informal or more structured, depending on the size of the project and the size of your organisation. You can sort out small projects with ad-hoc input from a team of just two or three members. Major investments will require a more rigorous approach perhaps involving five or six members with a formal meeting format. Even in the smallest organisation it is essential that the team includes someone with knowledge of the refrigeration systems and someone with responsibility for finance. All capital investment projects have tax implications and only someone who is aware of current legislation can ensure that these are taken into account.

A ‘typical’ team for a medium-sized project is likely to include:

- an engineering manager, to provide the technical input;
- an operations manager, to provide data on production volumes, load variations, maintenance, etc.;
- an accountant, to calculate financial savings, determine cash flows and assess taxation implications.

You need an effective project leader

In some circumstances it may be appropriate to include the health and safety manager or the environmental manager. It may be of benefit to include an external refrigeration specialist to provide expert help in this important area. There is no ‘right way’ to structure the team; it must be tailored to suit the needs of the project concerned. Once the team has been set up, it is essential that responsibilities are clearly allocated. A ‘project champion’, often the engineering manager, must be identified and will be responsible for co-ordination of all activities. Good Practice Guide 213, on successful project management, examines common reasons why projects fail or overrun - the key problem identified is lack of an effective project champion!

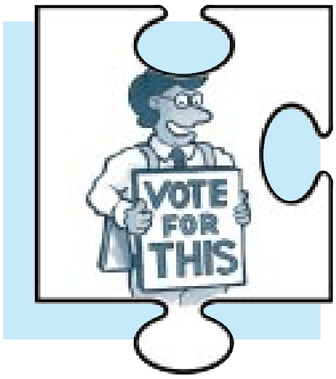
NatWest Group Property….

The bank commissioned a new data processing centre at Stone, Staffordshire. Using a teamwork approach the bank developed and built a highly efficient and cost-effective cooling system.

The team analysed the cooling requirements of the computer systems and proposed four potential solutions including a low first-cost direct expansion chiller and more sophisticated alternatives. Following guidelines agreed with the finance department, the building services expert carried out a discounted cash flow analysis of the total costs of the four alternatives, considered over the life of the plant, taking account of capital cost and the subsequent costs of energy, maintenance and component replacement.

A thermosyphon system, taking advantage of free cooling in cool ambient conditions, was shown to be the most cost-effective option and has now operated successfully and economically for six years.

….an example of teamwork in action.



4. SELLING THE PROPOSAL

In every organisation investment funds are limited. Your project will be competing for these limited funds, usually against many other projects. The chance of success depends largely upon the way you present and sell your proposal.

As in any selling exercise, you must understand the needs of the buyer; in this case, the manager who has to authorise your proposal. In most cases this person will not be interested in, indeed may not understand, the technicalities of refrigeration. Consequently, including a mass of technical detail in your proposal is likely to be counter-productive. The golden rules must be:

- keep it simple;
- avoid technical jargon;
- concentrate on the ends (the benefits), not the means.

Concentrate on the benefits

In selling the benefits consider alternative ways of presenting the same information; for example, buying new energy-efficient freezer plant will reduce energy consumption. This could be presented as:

- a reduction of p% in the energy consumption;
- a saving of £q per annum;
- an increase in annual profits of r%;
- equivalent to additional sales of £s per annum;
- a reduction in unit cost of £t.

Present a clear financial picture

You must decide which of these presentations is likely to have the greatest impact on your ‘buyer’. Use graphs to clarify the message. You must also consider the full range of benefits not simply the reduction in energy consumption. These may include:

- capacity to handle greater volumes;
- improved reliability (and customer confidence);
- lower maintenance costs;
- improved environmental impact and PR potential;
- improved working conditions;
- health and safety aspects.

Amplify the secondary benefits

It will not always be possible to quantify these benefits in financial terms but this should not inhibit you in referring to them. To be sure that all areas of benefit are considered it is essential to involve every member of the project team in the preparation of the submission. This will also ensure they are all conversant with every aspect of the proposal and able to explain its merits to their manager and colleagues. They can therefore pre-sell it within their own circle of influence before it is formally presented. In this way, support from decision-makers can be won and any adverse comments from ‘decision blockers’ can be addressed.

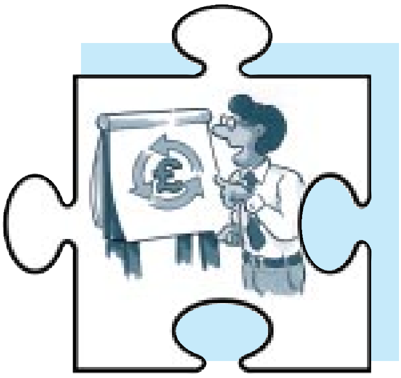
Pre-sell the project to decision-makers

Undoubtedly the most effective selling aid is a **history of successful projects**. For this reason it is important that:

- actual results are measured and savings compared with those planned;
- proposals do not exaggerate potential benefits;
- sufficient attention is given to detailed plant design;
- the project, once authorised, is properly managed.

Build on previous success

No effort should be spared to ensure that the forecast benefits are at least met and preferably exceeded. You should then vigorously publicise the results!



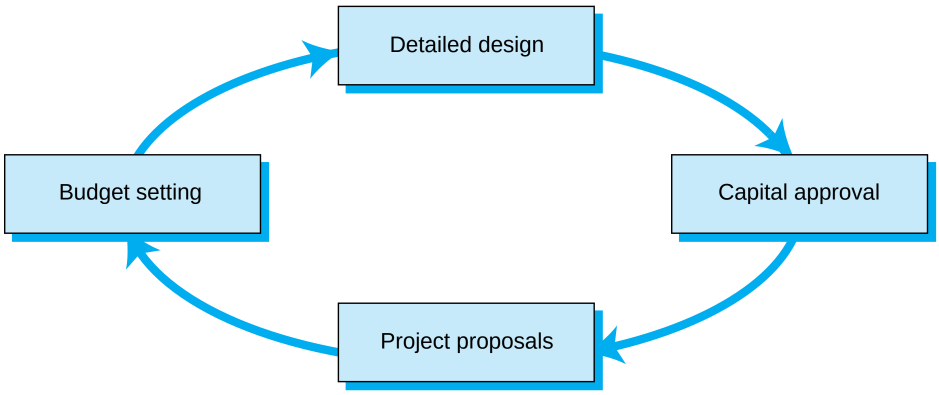
5. THE INVESTMENT CYCLE

Improving refrigeration plant efficiency usually involves initial expenditure of two types, revenue and capital. Revenue expenditure (e.g. for refrigeration plant maintenance) is included in the current year's cost figures and is deducted from sales income when calculating profits. Capital expenditure (e.g. for purchase of new equipment) is not included in the current year's cost figures but is spread over the anticipated life of the plant purchased (depreciation).

Your project competes for funds

Capital expenditure involves spending relatively large sums of money on projects with long-term consequences. The funds available are limited and usually exceeded by the demand. Consequently, there is internal competition for investment funds and approval will be given only to those projects that pass a rigorous examination.

Capital investment can be considered as a cyclical process:



Understand and exploit the cycle

The approval process starts at the time the annual budget is set, when managers detail the sums they wish to spend on capital in the next year. The degree of detail will vary in different organisations. At one extreme it may be necessary to give a description and estimated cost of each project envisaged; at the other, only the total expenditure will be required. Inclusion in the budget does not of itself authorise a specific project. Before it can start, the project will require a formal submission and approval.

If the investment is not carefully planned....

A drinks company made a hurried investment in a large new chiller. They set a low project budget before costed proposals were received. Corners were cut to make the project fit the budget. Six months after installation a post-project audit showed that the plant was performing unreliably and using 20% more energy than necessary. The costs of putting things right were massive in comparison to the costs of better initial planning and design.

....the avoidable extra costs can be considerable.

Have projects ready for new funds

You may not always enter the investment cycle at the proposals stage. You may be reconsidering old ideas or fitting small sub-projects into a larger budget set by others. You must understand your company's investment cycle in order to maximise your projects' chances. Find out when annual budgets are set and make sure that your requests for capital funding meet the deadlines. Annual budgets can change, so you should also have a portfolio of fully costed projects that you can implement at short notice, so that you are ready if extra funding becomes available. Be aware of next year, and prepare your case.

6. FINANCIAL APPRAISAL METHODS

There are three different financial appraisal methods in common use:

- payback period;
- return on investment (RoI);
- discounted cash flow (DCF) techniques, which include net present value (NPV) and internal rate of return (IRR).

Each approach has a different role to play in assessing financial viability, with its own advantages and disadvantages. Organisations will have a preferred method which you and your team should use. Payback period is easiest for someone without financial training to understand and apply. In the absence of company guidelines use payback period for small/medium-sized projects. Only use DCF for what you consider a major investment. Because DCF is a detailed technique, the use of payback period during preliminary screening of options may be more appropriate.

Method	Advantages	Disadvantages
Payback period	Simple to apply. Favours projects with quick return.	Savings beyond breakeven (payback) are ignored.
Return on investment	Includes all costs over the life of a project.	No account taken of getting early return.
Discounted cash flow	Includes savings over the life of a project. Weight is given to projects with an early return on the investment.	Selection of discount rate can be arbitrary. Complex to apply.

Payback Period

The net annual savings are estimated and a cumulative total obtained. The time taken for the cumulative total to equal the initial investment is called 'the payback period'. Most organisations will have a target payback period that must be achieved for an investment to be acceptable. Payback period is a very popular technique for energy efficiency investments, which tend to be relatively small and low in risk.

Return on Investment

The average annual profit over the life of the project is expressed as a percentage of the initial investment to find the 'return on investment'. This is compared against the organisation's target RoI to judge the acceptability of the investment. The project lifetime needs to be defined.

Discounted Cash Flow

DCF reflects the fact that a sum of money received at a future date is worth less than the same sum of money received today. This arises because money available now can be invested and would accumulate interest. The longer the delay in obtaining money or the higher the assumed interest rate, the less is its value today or its 'present value'. There are a number of ways in which DCF can be used in appraising capital investment proposals, the most common one being **net present value**. This involves factoring the forecast savings for each year of the life of the project at a selected discount rate. The discounted savings are then totalled for the life of the project and if the sum of the discounted savings is the same as, or greater than, the initial investment, then the investment is acceptable. An alternative DCF technique is **internal rate of return**. The IRR is the discount rate for which the NPV of an investment equals zero. DCF techniques should only be used in consultation with company financial specialists.

Good Practice Guide 69 *Investment Appraisal for Industrial Energy Efficiency* and Good Practice Guide 213 *Successful Project Management for Energy Efficiency* provide more detailed information on financial appraisal methods.

7. IDENTIFYING PROJECTS

The first step in the investment cycle is to identify the projects in which you would like to invest. Normally this takes place before preparing the budget submission. Potential projects can be developed in two ways:

Consider all options - be strategic

- In a **strategic approac**h the end-user conducts a systematic review of all potential investment opportunities, each of which is then evaluated both financially and in terms of the level of energy savings achievable. Possible projects are placed on an 'opportunity list' arranged in descending order with the investment showing the best financial return at the top. As circumstances change, projects are added to the list. The refrigeration user then knows that if he implements the projects in list order he will improve the plant in the most cost-effective way available at that time.

Cherry picking doesn't guarantee the best results

- The alternative is a **project approach**, in which projects are individually assessed and put forward if they pass the necessary technical and financial hurdles. Projects are often considered in this way because the work is 'essential' (e.g. replacement of old plant), or simply because it is easier to apply. Whilst this approach is very common it does not guarantee that the best investments are made. It may reduce the chance of obtaining board approval.

Update your opportunity list

The opportunity list should be kept up-to-date. It will be invaluable when preparing the budget submission and subsequently when deciding which projects to encompass within the agreed budget. For this reason it is essential that you commit sufficient effort and expertise to its preparation. If, for example, you spend £50k per annum on electricity for refrigeration, the potential savings are at least £10k per year. It is therefore worth committing a reasonable amount of internal or external resource to investigate how this potential can be realised.

Use a structured analysis

The strategic approach is complicated by the sheer number of possible options. There are literally hundreds of different ways in which refrigeration plant efficiency can be improved. Finding the best options to apply in a given situation requires a considerable degree of experience and expertise. In this short Guide it is impossible to illustrate all of these opportunities. Other Department of the Environment, Transport and the Regions' publications such as Good Practice Guides 36, 37, 42 and 44 give some very helpful and detailed suggestions. Energy saving opportunities for refrigeration plant can be conveniently structured into four separate categories. These are explained below and on the page opposite some specific examples are listed.

I. ***Cooling load*** opportunities relate to the process being cooled (rather than to the refrigeration plant itself). It is often possible to eliminate or reduce a cooling load. This can have a tremendous impact on the running costs of refrigeration plant. At the design stage, reducing the load should also reduce the capital cost of a refrigeration system. Careful appraisal of cooling loads is a critical part of identifying refrigeration efficiency opportunities.

II. Once the cooling load has been minimised it is then logical to appraise the ***system design***. This encompasses issues such as the cycle configuration and the way in which the plant responds to part load operating conditions.

III. ***Component design*** opportunities relate to the detailed design and selection of individual components within the chosen system design.

IV. The fourth energy saving category is ***operation and maintenance***. It is very common to encounter refrigeration systems that are operating well below their potential level of efficiency and capacity. This is usually because routine maintenance is neglected!

Category I Cooling Load

Reduce heat gains	GPCS 223/350
Specify evaporator fans carefully, avoiding excessive air flow by using variable speed drives	GPCS 230/302
Use variable speed secondary refrigerant pumps	GPCS 89/124
Install efficient lights and manage their use	GPG 44
Avoid excessive defrost	GPCS 302
Maximise room and pipe/vessel insulation	GPG 44
Avoid parasitic loads (e.g. hot pipes in a cold room)	GPG 44
Do not overcool	GPG 44
Try to use ambient precooling	FEB 11
Use heat exchange with cold process streams*	CADDET 149

Category II System Design

Consider more than one temperature level if cooling demands exist at differing temperature levels*	GPG 44
Design for high part-load efficiency	GPG 59
Design for high winter time efficiency	GPG 59
Avoid head pressure control	GPCS 302
Use the most suitable refrigerant	FEB 11
Design to minimise unloaded compressor operation	GPG 59
Consider desuperheaters and heat recovery condensers	CADDET 149
Consider thermal storage for peak load avoidance*	CADDET 61
Use two-stage cycles for large temperature lift*	FEB 11
Use plants in series for large temperature range	GPG 44

Category III Component Design

Select compressors for high energy efficiency	GPG 59
Size compressors to avoid running at low load	GPG 59
Use large evaporators and condensers	GPCS 230/301
Avoid direct expansion evaporators if possible*	
Design evaporator for easy oil removal*	
Optimise auxiliary power use carefully	GPCS 89/124/230
Specify high efficiency motors	GPG 02
Consider condenser air purgers*	GPCS 92
Ensure appropriate pipe sizing	GPG 44

Category IV Operation and Maintenance

Record plant conditions and use to identify trends	NPFP 76, GPCS 230
Minimise head pressure at all times	GPCS 92/248/302
Make sure condensers or towers are well ventilated	
Keep air-cooled condensers clean	GPG 42
Monitor refrigerant loss and repair all leaks	GPG 178
Keep a log of oil added/removed and drain regularly	GPG 42
Make sure defrosting systems work efficiently	
Avoid electric defrosting during peak cost hours	
Clean the evaporators as required	GPG 42
Purge condensers if necessary	GPCS 92

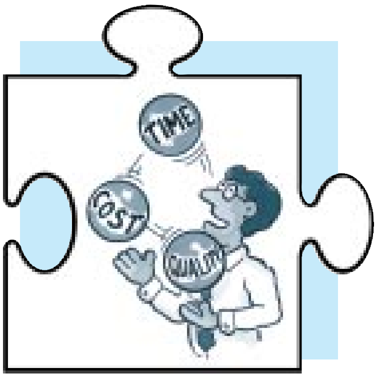
See 'Further Information' for references to useful publications. Guides GPG 36, 37, 42 and 44 are generally applicable.

When replacing evaporators, size generously and position for good air circulation. Consider using highly efficient fans in your evaporators.

Installing an automatic purging system saves money and payback is usually less than one year. One company saved over £8,000.

When replacing condensers, think big. This evaporative condenser was generously sized and is saving one company £1,250 a year.

* These techniques are mainly applicable to larger refrigeration systems (e.g. over 100kW).



8. PRIORITISATION AND FUNDING

When comparing a group of potential projects, the initial ranking will be based on a financial analysis. However, it is usual for the financial ranking to be modified to take into account the various prioritisation and selection issues described in this section.

Do not ignore the engineering detail

Financial ranking. Projects are ranked in the order established by the financial appraisal, creating an opportunity list such as that shown on the right. Capital cost estimates must be carefully refined to ensure that detailed issues (such as civil engineering work) have not been overlooked. Running cost savings must be based on proper consideration of the annual cycle of operation, including maintenance and staffing as well as energy costs.

Financial Ranking Table

Project	Capital cost £k	Saving £k/year	Payback months
A	3	3	12
B	35	26	16
C	30	20	18
D	90	45	24
E	70	30	28
F	75	25	36

Always take advantage of overriding issues

Overriding issues. Special circumstances may influence project selection, for example:

- the need to replace an old piece of essential plant;
- the need to phase out CFC refrigerants;
- the construction of a new factory or process line;
- the need to meet new Health and Safety legislation.

Paybacks are always improved by marginal cost analysis

In these circumstances purchase of refrigeration plant may be essential. However, alternative designs will require different levels of capital investment and have different energy costs. You can now assess the economic case for an energy-efficient design on a **'marginal cost' basis**. Only the difference in capital cost (or marginal cost) between a 'conventional' and a more efficient plant needs to be set against the resulting savings in energy costs. For example, Design A costs £20k to install and £7k per year to run. Design B costs £24k, but the running costs are only £5k per year. The payback period of the marginal increase in capital cost (i.e. £4k) is just 2 years (given the savings of £2k per year).

The best time to make investments in refrigeration efficiency is when an overriding issue exists. Unfortunately, this often coincides with a time when managers are particularly busy and efficiency issues are at the bottom of their list of priorities. **Senior managers must be made aware that efficiency investments are worth pursuing - mistakes made at this stage lead to increased running costs for many years to come.**

Strengthen the case with other benefits

Secondary issues. Prioritisation of projects will be influenced by secondary parameters that are often difficult to quantify financially. These include factors such as *environmental impact, improved flexibility* and *improved reliability*. The team should ensure that it is fully aware of relevant company policy and emphasise those secondary benefits most likely to be attractive to senior managers. The environmental impacts of refrigeration efficiency projects are particularly significant. Environmental statements are usually endorsed at board level, and an environmentally helpful refrigeration project could receive support. Some companies take full advantage of the public relations elements of such investments. All refrigeration efficiency projects reduce the global warming impact. Whilst these benefits may not in themselves justify an investment they help to strengthen the investment case.

Having addressed the various overriding and secondary issues, you are now in a position to modify your priorities and produce the **Project Selection Table** as shown below. Now the projects are in a revised order, taking into account the 'comments column' as well as the financial ranking.

The Project Selection Table helps clarify priorities

Capital rationing. The Project Selection Table not only shows different priorities, but also acts as a helpful tool to decide which projects should actually proceed, given budgetary constraints and limited capital. In the example given in the table, £220k had been made available for refrigeration efficiency projects. The blue line on the table represents this budget limit, in terms of the cumulative cost of all projects (shown in the third column). It is only possible to implement projects B, D, A and F. Projects C and E cannot proceed even though they appear attractive in isolation. If a small amount of spare capital suddenly becomes available from another budget your Project Selection Table enables you to propose 'spare' projects that can quickly fill the hole in the budget.

Project Selection Table

Project	Capital cost £k	Cumulative capital cost £k	Payback months	Comments
B	35	35	16	Essential plant
D	90	125	24	New process
A	3	128	12	
F	75	203	36	Environmental benefit
C	30	233	18	
E	70	303	28	

Budget limit

Funding

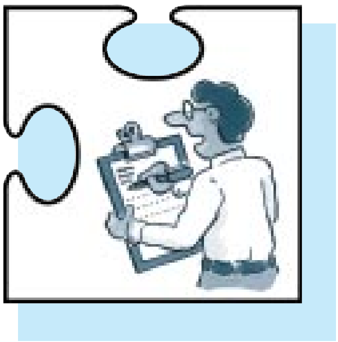
If an organisation is short of cash then even those projects which meet the normal financial requirements may be rejected. A way around this problem may be to consider an alternative form of funding for the project, such as hire purchase or leasing. Both of these approaches enable an organisation to obtain the use of an asset without having to find the cash in advance. The accounting treatment and the tax implications of the transaction will depend upon the funding arrangement but will be significantly different from an outright purchase. The timing of cash flows will differ from purchase and therefore any DCF calculations will have to reflect the nature of the funding. In the energy efficiency field 'third party funding' has become very popular in recent years, although it has not often been applied to refrigeration projects. There are a number of specialist contract energy management (CEM) companies offering this service and several of the electricity utilities are keen to invest in efficiency projects.

Alternative funding methods can change priorities

Restricted capital investment funds....

A food distribution company was considering a major investment in efficient refrigeration equipment. Although the project was financially attractive the company had other urgent requirements for capital funds, so the project could not go ahead with in-house funding. A specialist contract energy management company was approached and a mutually beneficial third-party funding contract was developed. The CEM company designed and funded the new equipment and then had responsibility for its operation. Efficiency savings were shared between the two companies.

....problem solved by contract energy management approach!



9. DATA REQUIREMENTS

Comprehensive data are required for detailed technical and financial project analysis. Once again, a structured approach will ensure that the various options can be compared on an equal basis. The five main purposes of data gathering are:

Detailed analysis strengthens your case

- to help identify design options;
- to appraise the capital cost of each option;
- to appraise the running costs of each option;
- to help assess secondary benefits such as reduced environmental impact;
- to launch discussions with equipment manufacturers and contractors.

Some of the data required are similar to that gathered for any well-structured engineering investment exercise. Examples of such data are listed opposite.

Assess the annual operating envelope

Understand the cooling load and heat rejection

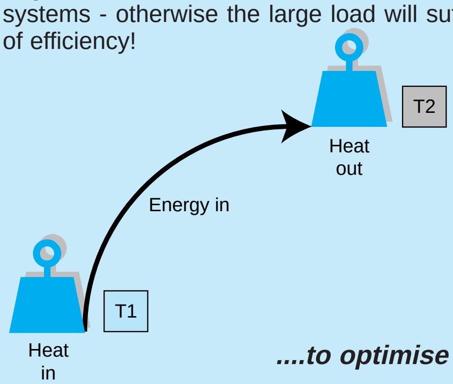
However, some data requirements are quite specific to refrigeration. One of the most common mistakes in refrigeration design is that only the 'design point' is considered. This usually combines the highest heat load and the hottest ambient conditions. Most refrigeration plants spend little time at this design point - they mostly operate at lower heat loads and under cooler ambient conditions. To optimise the efficiency of a refrigeration system it is essential to take into account the annual cycle of operation in terms of variations in the size of cooling load and variations in ambient temperature. Without good data to model cooling load and ambient temperature variations it is quite impossible to identify some of the Category I cooling load opportunities and Category II system design opportunities described in Section 7.

Establish the temperature range of each load

Another common design mistake is to group several loads of different temperature levels on the same plant. This is likely to be very wasteful, as refrigeration plant efficiency is highly sensitive to temperature lift. It is vital to gather data on the temperature level and temperature range of each cooling load.

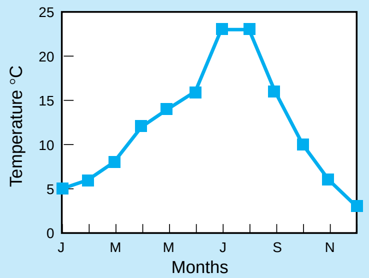
Think about temperature lift....

Think of your refrigeration plant like a lift. Heat is being 'lifted' from a low temperature level to a higher one. The energy input is remarkably sensitive to temperature lift (the difference in temperature between the evaporator, T1 and condenser, T2). Just a 1°C rise in lift leads to another 2% to 3% of energy input! Always minimise the lift. Keep condensing pressures as low as possible. It is also important to raise evaporating pressure. If you have a large load at 10°C and a small one at 0°C, you need two systems - otherwise the large load will suffer a 20% loss of efficiency!



....to optimise your design.

Weather affects refrigeration....



This graph shows typical UK average monthly ambient temperatures. Many refrigeration plants are optimised for a peak design temperature of, for example, 28°C which rarely occurs. The plant must be designed to take advantage of the fact that the majority of running hours are spent at much lower ambient temperatures. Many plants run at a fixed head pressure - based on this peak temperature! Savings of 25% can be made by allowing head pressure to float downwards. Do not forget - electricity is most expensive in winter!

....optimise for average conditions.

Operational Data

Peak product throughput

Variations in throughput, hourly basis for typical operating weeks

Variations in throughput, seasonal basis

Peak product cooling requirements

Variations in cooling requirements

Weather data - peak design dry bulb and, if appropriate, wet bulb temperatures

Weather data - average seasonal temperatures (monthly is usually sufficient, but take care if, for example, the plant operates only during the day)

Standby requirements

Technical Data

For cooling load analysis:

- peak duty, minimum duty
- variations in load on an hourly and seasonal basis (allowing for variations in production requirements and ambient temperatures)
- temperature levels and range of each cooling load

For heat rejection analysis:

- options for cooling (air, tower water, etc.)
- ambient temperature profiles

Financial Data

To assess running costs:

- electricity prices, allowing for daily and seasonal variations
- other utility prices (e.g. water), if required
- allowances for changing utility prices
- manpower costs - operational
- manpower costs - regular maintenance
- other maintenance costs, e.g. oil, refrigerant, water treatment chemicals
- cost of major planned overhauls
- allowances for unforeseen problems

To assess capital costs:

- cost of main refrigeration equipment
- cost of electrical supply to plant (panels, cables, starters, transformers, etc.)
- cost of civil and structural work
- cost of control and instrumentation
- cost of installation and commissioning
- allowance for staff training
- allowance for interruptions to production during installation

For financial analysis:

- interest rates
- pattern of cash outflow during plant purchase phase
- pattern of cash inflow (savings) and outflow (revenue costs) during operational phase

GLOSSARY OF USEFUL TERMS

TECHNICAL TERMS

CFC	chlorofluorocarbon, a refrigerant chemical now proven to damage the ozone layer and contribute to global warming.
Coefficient of Performance (COP)	the ratio of the cooling capacity to the absorbed power of a compressor. A key measure of refrigeration plant efficiency.
Coefficient of System Performance (COSP)	the ratio of the cooling capacity to the absorbed power of a refrigeration system. This measure includes the effect of the power consumption of often forgotten auxiliary components such as fans and pumps, as well as the compressor.
Compressor	a machine which raises the pressure and temperature of a gas.
Condenser	a heat exchanger in which a vapour gives up heat and condenses.
Condensing Temperature and Pressure	the temperature and pressure at which the refrigerant condenses.
Defrost	removal of frost from the surface of an evaporator.
Direct Expansion (DX) Evaporator	an evaporator in which all the refrigerant supplied to each parallel circuit completely evaporates in that circuit, producing superheated vapour at the outlet.
Electronic Expansion Valve (EEV)	an expansion valve controlled by microprocessor and able to operate under relatively low and varying conditions of pressure difference.
Evaporating Temperature and Pressure	the temperature and pressure at which the refrigerant evaporates.
Evaporative Condenser	a condenser in which refrigerant within tubes is cooled by a falling water spray and a countercurrent flow of air.
Evaporator	a heat exchanger in which a liquid vaporises producing cooling.
Expansion Valve	a valve through which liquid refrigerant passes and reduces in pressure and temperature.
Floating Head Pressure	a refrigeration system that allows the head pressure to vary in line with the ambient weather conditions (i.e. head pressure control **not** used).
Flooded Evaporator	an evaporator in which only partial evaporation takes place, producing saturated vapour at the outlet.
Head Pressure	pressure at compressor outlet. Approximately equal to (and usually synonymous with) the condensing pressure.
Head Pressure Control	operation of the condenser at an unnecessarily high pressure (under the prevailing load and temperature conditions).
Open Compressor	a compressor driven by an external source and requiring a shaft seal.
Pull-down time	time taken for a system to achieve its running temperature, starting from ambient.
Purging	removal of air or non-condensable gases from the high pressure side of the refrigeration circuit.
(Primary) Refrigerant	the working fluid of the refrigeration system which absorbs heat by vaporising in the evaporator and rejects heat by liquefying in the condenser.
Secondary Refrigerant	a fluid which is cooled in the evaporator by heat exchange with the primary refrigerant and then circulated to provide cooling of remote loads (also known as a 'heat transferring fluid').
Semi-hermetic Compressor	a compressor directly coupled to an electric motor. Compressor and motor are contained within a single gas-tight bolted enclosure.
Temperature Lift	the temperature difference between the evaporating and condensing temperatures.
Temperature Range	the temperature reduction of the cooled stream across the evaporator.
Thermostatic Expansion Valve (TEV)	a valve which regulates the flow of refrigerant into the evaporator in response to the degree of superheat of the refrigerant leaving the evaporator.

FINANCIAL TERMS

Balance Sheet	a statement showing, at a point in time, where a company obtained its investment (shareholders, loans, retained profits, etc.), i.e. the liabilities, and where it invested it (fixed assets, stocks, debtors, etc.) i.e. the assets.
Capital Employed	the amount of money invested in a business by the shareholders plus retained profits and long-term borrowings.
Capital Expenditure/ Investment	expenditure on fixed assets. Capital expenditure is not taken into account when calculating profits.
Cash Flow	the sums of money that flow both into and out of a business.
Cost of Money	the rate of interest an organisation has to pay in order to borrow money. It is one of the factors which will determine the discount rate used in DCF calculations, the other one being the return on capital employed currently being achieved.
Depreciation	the amount deducted from the value of a fixed asset each accounting period. It is calculated by dividing the cost of the asset by the anticipated life to determine the depreciation charge per month/year. Depreciation is treated as a cost when calculating profits but does not affect cash.
Discounted Cash Flow	a method of financial appraisal which takes account of the timing of the financial benefits derived from an investment.
Discounting	a financial calculation which has the effect of converting sums of money received at some future date to their current equivalent value. The calculation is concerned only with the interest that can be earned over time on money available today and takes no account of inflation.
Financial Appraisal	an assessment of the financial consequences of a proposal for capital expenditure.
Fixed Assets	items owned by a business for over a year for use in the manufacturing/marketing/ administrative process. Usually confined to items costing a significant sum at purchase.
Internal Rate of Return	the rate at which the discounted values of the cash inflows is the same as that of the cash outflows.
Net Present Value	a financial appraisal method involving the use of discount factors to convert the future cash flows resulting from an investment to a common base, i.e. the value now or ‘present value’. The present value of the cash outflows are set against the present value of the cash inflows to find the net present value. A positive NPV means that the investment meets the financial target set by the company.
Off-balance Sheet Finance	a means of acquiring the use of assets which avoids having these shown on the balance sheet. An example is where assets are leased rather than purchased.
Payback Period	the time it is estimated will be required for the additional profits stemming from a capital investment to equal the sum invested.
Present Value (Discount) Factor	a factor used to convert future cash flows to their equivalent value now at a given rate of interest.
Return on Capital Employed	the profit earned by a company expressed as a percentage of the capital employed, one of the key measures of company performance.
Trading Statement	a statement showing the sales, cost of sales, and hence, profit, a company has made over a period of time.
Working Capital	the amount invested in stocks and owed by debtors less the amount owing to creditors. It will tend to change in line with sales volume.

FURTHER INFORMATION

Useful Sources of Information

Energy Efficiency Enquiries Bureau
ETSU
(source of publications and efficiency advice)
Harwell, Didcot
Oxfordshire OX11 0RA

Telephone: 01235 436747
Fax: 01235 433066

Institute of Refrigeration
(for advice on all refrigeration issues)
76 Mill Lane
Carshalton
Surrey SM5 2JR

Telephone: 0181 647 7033
Fax: 0181 773 0165

Chartered Institute of Management Accountants
(for advice on accountancy issues)
Technical Department
63 Portland Place
London W1N 4AB

Telephone: 0171 917 9285
Fax: 0171 580 6355

British Refrigeration Association
(access to suppliers and contractors)
6 Furlong Road
Bourne End
Buckinghamshire SL8 5DG

Telephone: 01628 531186
Fax: 01628 810423

A range of Department of the Environment, Transport and the Regions and other publications provides valuable advice on refrigeration efficiency opportunities. Please phone the Energy Efficiency Enquiries Bureau for a list.

Detailed Technical Handbooks

Good Practice Guides

GPG 36	Commercial Refrigeration Plant: Energy Efficient Operation and Maintenance
GPG 37	Commercial Refrigeration Plant: Energy Efficient Design
GPG 42	Industrial Refrigeration Plant: Energy Efficient Operation and Maintenance
GPG 44	Industrial Refrigeration Plant: Energy Efficient Design
GPG 59	Energy Efficient Design and Operation of Refrigeration Compressors
GPG 69	Investment Appraisal for Industrial Energy Efficiency
GPG 178	Reducing Refrigerant Leakage
GPG 213	Successful Project Management for Energy Efficiency

Fuel Efficiency Booklets

FEB 7	Degree Days
FEB 11	The Economic Use of Refrigeration Plant

Real Examples of Efficiency in Action

Good Practice Case Studies

GPCS 89	Variable Speed Drives on Cooling Water Pumps
GPCS 92	Automatic Purging on a Cold Store Refrigeration Plant
GPCS 124	Variable Speed Drives on Secondary Refrigeration Pumps
GPCS 223	Night Blinds on Refrigerated Cabinets
GPCS 230	A New Refrigeration System in a Small Cold Store
GPCS 248	Energy Savings Whilst Eliminating CFCs With a New Refrigeration System
GPCS 301	Use of Larger Condensers to Improve Refrigeration Efficiency
GPCS 302	Improving Refrigeration Performance Using Electronic Expansion Valves
GPCS 350	Strip Curtains on Chilled Display Cabinets

Other Best Practice Programme Guides

FPP 21	Optimising the Operation and Design of Refrigeration Systems
NPFP 76	Refrigeration Fault Diagnosis System
NPFP 98	Efficient Coolers for Dispensing Drinks
ECG 37	Cold Storage Energy Consumption Guide

IEA CADDET Case Studies

CADDET 61	Cooling System for Fruit and Vegetable Storage Plant
CADDET 81	Energy Saving Computer Controlled F-Class Cold Storage System
CADDET 149	Refrigeration Heat Recovery System

The Government's Energy Efficiency Best Practice Programme provides impartial, authoritative information on energy efficiency techniques and technologies in industry, transport and buildings. This information is disseminated through publications, videos and software, together with seminars, workshops and other events. Publications within the Best Practice Programme are shown opposite.

Further information

For buildings-related publications please contact:
Enquiries Bureau

BRECSU
Building Research Establishment
Garston, Watford, WD2 7JR
Tel 01923 664258
Fax 01923 664787
E-mail brecsuenq@bre.co.uk

For industrial and transport publications please contact:
Energy Efficiency Enquiries Bureau

ETSU
Harwell, Didcot, Oxfordshire,
OX11 0RA
Fax 01235 433066
Helpline Tel 0800 585794
Helpline E-mail etbppenvhelp@aeat.co.uk

Energy Consumption Guides: compare energy use in specific processes, operations, plant and building types.

Good Practice: promotes proven energy efficient techniques through Guides and Case Studies.

New Practice: monitors first commercial applications of new energy efficiency measures.

Future Practice: reports on joint R & D ventures into new energy efficiency measures.

General Information: describes concepts and approaches yet to be fully established as good practice.

Fuel Efficiency Booklets: give detailed information on specific technologies and techniques.

Energy Efficiency in Buildings: helps new energy managers understand the use and costs of heating, lighting etc.